FINAL CONTRACT REPORT

NOAA CONTRACT - 50EANA700063

PROJECT COMPONENTS

NEFSC Pelagic Longline Data Review

&

Analysis of Gear, Environmental, and Operating Practices
that
Influence Pelagic Longline Interactions with Sea Turtles

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SUMMARY

The NOAA contract provided funds for work on two distinct but related tasks primarily involving pelagic longline observer data from the National Marine Fisheries Service (NMFS) - Northeast Fisheries Science Center (NEFSC) in Woods Hole, Massachusetts. The contract was monitored by the NMFS Northeast Regional Office (NERO) - Habitat and Protected Resources Division in Gloucester, Massachusetts. Dr. John J. Hoey was the principle investigator for the National Fisheries Institute, Inc. (NFI) in Arlington, Virginia.

The first project involved an extensive data quality review and data editing and recovery program for all observer data collected by the NEFSC on pelagic longline vessels between 1990 and 1995. The second project involved the subsequent analysis of that data, along with similar observer records from the NMFS Southeast Fisheries Science Center (SEFSC) in Miami, Florida. The combined NEFSC and SEFSC observer records were summarized by year, area, quarter, and/or month, and patterns in the occurence of longline interactions with sea turtles are described. Operating practices, gear characteristics, and environmental variables are described along with associated interaction rates. Status information with respect to how interactions occur and the condition of the individual turtles are described.

NEFSC Pelagic Longline Data Review

Data quality review, verification, and editing tasks were primarily conducted at the NEFSC with the contract assistance of Ms. Holly Yachmetz and supported by observer program personnel, most notably Mr. Mike Tork. Standard exploratory data analyses were conducted by John Hoey prior to visiting Woods Hole to identify missing and outlier records and to present all data in standard formats. These tasks were necessary since formats and data collection and coding procedures had changed between 1990 and 1995. Discrepancies in observed trips and numbers of turtles had been noted between analyses conducted by the principle investigator and analyses conducted by SEFSC personnel (Scott and Brown 1997). These discrepancies were resolved and 1,090 NEFSC set records were reviewed and edited where necessary. A number of significant data recovery and verification tasks were completed. All time and temperature variables at the start and end of set and haul operations for 465 sets between 1990 and 1993 were recovered from original forms and entered. For many of these sets, data on hook size, brand, and pattern numbers were recovered from original observer forms and entered into revised formats. The original formats used for 1990 through 1993 data did not include these variables. In those cases where observer notes on hook pattern were missing, previous and/or subsequent observed trips were reviewed and calls were made to vessel owners. For a number of trips, gear suppliers were contacted to ask them to review sales receipts for hook pattern information from sales preceding the observed trips.

Missing time and temperature variables in the 1994 and 1995 data were edited. Set location data. latitude and longitude rather than NEFSC sampling area. missing from keypunched records was recovered. Most of these records were from sets observed on the Grand Banks or from areas south of Cape Hatteras. Bottom depths and gear parameters (gangion and dropper lengths, monofilament pound test, hook sizes and patterns, and baits) were verified and edited where necessary. The verification of outlier values for bottom depth and gear parameters (ie. hooks between floats, dropper lengths, and gangion tests) revealed that a small proportion of the sets (@ 10% in one year) appeared to be directed at large coastal sharks, rather than swordfish or tuna. An examination of the original observer forms corroborated this fact.

The final data review task involved examining NEFSC turtle interaction forms for status (alive/dead), action, disposition, condition, and entanglement codes. Available size estimates for individual turtles were verified and edited where necessary. During this review, four (4) additional turtles were identified in the original records that had not been keypunched. Several species identifications were also revised. This was not unexpected since all of these changes were associated with the two or three trips that accounted for the largest number of turtle interactions. While the overall number of turtles increased by four (4), resolving the discrepancies between previous analyses resulted in ninty-four (94) additional set records. Particular attention was devoted to gear involvement and entanglement codes in 1994 and 1995 and in recovering this information when it was recorded on the forms used in the earlier period. This later task was extremely difficult given the frequent code changes that occurred during 1993, the number of observations and possible combinations of gear and interaction circumstances, and the differences in quality and completeness of notes recorded by different observers. This portion of the project was conducted almost exclusively by Ms. Yachmetz, in recognition of the potential sensitive issue of a non-NMFS scientist editing or interpreting information on turtle conditions. Both Ms. Yachmetz, Mr.Tork, and Dr. Hoey agree that there is a need to thoroughly review and standardize interaction and condition codes and associated decision protocols. Recommendations for future work on this topic will be provided in a later section.

Analysis of Gear, Environmental, and Operating Practices that Influence Pelagic Longline Interactions with Sea Turtles

The SEFSC and NEFSC Pelagic Longline Observer Programs have deployed observers aboard longline vessels on 395 trips between 1990 and 1996. A random vessel selection process, based on logbook reported effort by vessel and area from the previous year, has been used to deploy observers. Observers monitored 2,942 sets which accounted for 1,921,294 hooks. The total observed catch of all species was 98.036, including 501 observed sea turtles. Loggerhead, *Caretta carett* (266) and leatherback, *Dermochelys coriacea* (208) turtles are the predominant species (94.4%) reported in interactions with pelagic longline gear. Fifteen (15) green turtles were recorded, along with one (1) Kemp's Ridley, and eleven (11) turtles that could not be identified to species. Species identifications of green turtles, *Chelonia mydas*, especially on the Grand Banks, and the single Kemp's ridley, *Lepidochelys kempii*, are questionable. Eight (8) of the 15 green turtles were identified by the same observer on a single trip. Of the 501 turtles reported, observers classified 493 as released alive, 6 as dead, and 2 in unknown condition. While 501 sea turtles were observed, some might have been caught more than once (on subsequent days) based on observer reports of clean hooks already in the jaw. Multiple captures were most likely on the three or four trips with the highest number of interactions based on comments from an interviewed captain.

The top eight (8) trips in terms of turtle interactions all occurred near the Grand Banks where a disproportionate number of turtles, especially loggerheads, were recorded. The top 8 trips, 2% of the total trips observed, accounted for 5% of the sets (146 out of 2,942) and 51.5% of the reported turtles. In this area there were dramatic yearly differences in interaction rates with 170 sets accounting for 50 turtles between 1990 and 1993, while 126 sets in 1994 and 1995 accounted for 244 turtles. Sea turtle interactions in the Grand Banks region are the dominant feature in the observer data, influencing analyses of environmental, gear and operating practices.

On a per set basis, 90% of the observed sets had no turtle interactions, 7% interacted with one turtle, and 3% involved interactions with multiple turtles. Loggerhead and leatherback turtles had different probabilites of multiple captures on the same set. For loggerheads 68.1% were caught on sets with other loggerheads (31.9% caught singly), whereas only 31.7% of leatherbacks were caught on sets with other leatherbacks (68.3% caught singly). This indicates that leatherbacks are more solitary whereas loggerheads tend to aggregate.

The numbers of multiple interactions differ not only by species but also by area. The Grand Banks area (NED) is the only area where interactions of four (4) or more turtles occur on a single set and there are eighteen (18) sets with three turtles and twenty-two (22) sets with two turtles. In the mid-Atlantic bight (MAB) and Northeast Coastal (NEC) areas there were three (3) sets that captured three turtles and eleven (11) sets that captured two turtles. In the remaining areas south of Cape Hatteras, there were seven (7) sets that captured two turtles. Multiple captures of sea turtles are clearly more prevalent on the Grand Banks and off the northeast coast where fall concentrations appear to be asociated with Gulf Stream water or Gulf Stream eddys.

Based on preliminary analyses of operating, gear, and environmental conditions the affect of area and season provides the dominant influence on sea turtle interactions, especially loggerhead turtles in the late summer and fall near the Grand Banks. Setting gear in sea surface temperatures equal to or exceeding 69 F would seem to increase the probability of encountering sea turles, especially in the fall when these temperatures are associated with warm core rings or the Gulf Stream. With respect to gear and operating practices, based on the available information small reductions in the probability of encountering sea turtles might be obtained by delaying the start of gear setting until after 1800 hours (6 pm), by setting 4 or more hooks between floats, and by using dropper and gangions that are longer in total length than 100 feet in length. Based on the preliminary analyses conducted to date, lightstick use does not appear to be a particularly influential variable, especially in comparison to the influence of temperature and frontal zone strength. Careful attention to conditions along a frontal system followed by attempts to fish colder and slightly deeper once turtles have been seen early in a trip, provide the best opportunity to limit subsequent interactions. Additional gear changes may be justified once analyses are conducted with respect to circle hooks and leatherback interactions in the Gulf of Mexico.

SAMPLING CHARACTERISTICS

The NOAA/NMFS observer program for pelagic longline fisheries for swordfish and tuna has deployed observers from both the Northeast and Southeast Fisheries Science Centers starting with two trips from the NEFSC in 1990. While these programs have coordinated deployments and selection procedures in recent years and have standardized data collection protocols, fluctuating funding between the centers has resulted in different annual sample coverages by area and quarter of the year. Figure 1 displays the standard reporting areas that will be used throught this report. These areas are the latest modifications of the reporting areas for pelagic logbook, observer, and ICCAT landing reports developed by the SEFSC (Cramer 1996). Sets were not observed in area 11 between 1990 and 1996. The number of observed sets, sets that interacted with turtles (positive sets), and the number of turtles are listed by year in table 1. Tables listing the number of observed sets by area, quarter, and year are provided in Appendix 1. The number of observed trips by area and quarter are provided in Appendix 2.

Figure 1. Geographic areas used in subsequent summaries of NEFSC and SEFSC Pelagic longline observer data from 1990 through 1996.

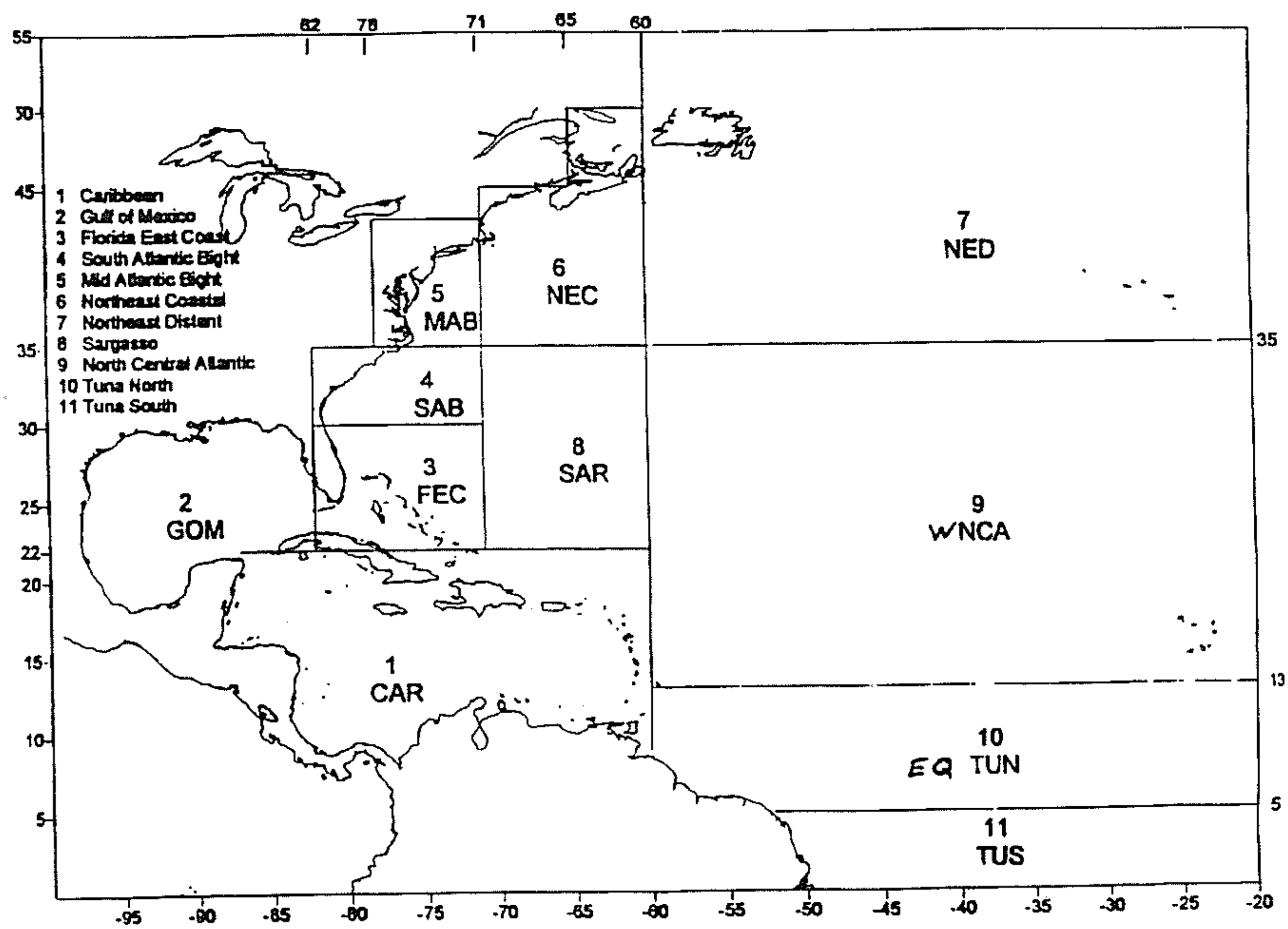


Table 1. Observed Sets and Sea Turtles by Haul Year.

YEAR	SETS	POSITIVE SETS	TURTLES
1990	23	0.00	0.00
1991	48	7	9
1992	332	36	46
1993	827	76	93
1994	651	71	135
1995	699	89	195
1996	362	21	23
TOTAL	2,942	300	501

During 1990 and 1991 all observed sets were located north of 35 degrees North latitude (Cape Hatteras, N.C.) during the third and fourth quarter. In 1992 no observations were reported during the first quarter. In 1996 no sets were observed in area 7 (NED) and only 6% of the sets were located north of Cape Hatteras as compared against 56%, 41%, 46%, and 38% in 1992,1993, 1994, and 1995, respectively. These differences in regional sampling rates between years must be carefully considered when analyzing this data. Subsequent summaries combine data across years. While this can partially compensate for the differences between years, this will only be true if inter-annual variability (in catch rates or year-class strengths) is less significant in terms of overall variability when compared against region and season affects.

A preliminary examination of catch rates per set clearly indicated, as will be demonstrated subsequently, that interactions for loggerhead turtles, and to a lesser extent leatherbacks, were more prevalent north of Cape Hatteras (areas 5, 6, & 7). While catch rates could be presented in terms of catch per 1,000 hooks or catch per set, the later is easier to understand (fewer decimal places) and will be used in table 2 for loggerhead catch rates and table 3 for leatherback catch rates. Inter-annual variability is documented by listing the mean, median, and standard deviations of catch per set for the Mid-Atlantic Bight (area=5),Northeast Coastal (area=6), and Northeast Distant (area=7) areas. These areas accounted for 88% of the loggerhead interactions and 73% of leatherback interactions. Figure 2 provides 3-d plots of numbers of observed sets and numbers of turtles by area and year for these areas.

Table 2. Loggerhead turtle interaction rates in number per set by area and year for the Mid-Atlantic Bight, Northeast Coastal, and Northeast Distant areas. Mean, median, and standard deviations are provided.

VARIABLE - LOGGERHEAD TURTLES - NUMBER PER SET

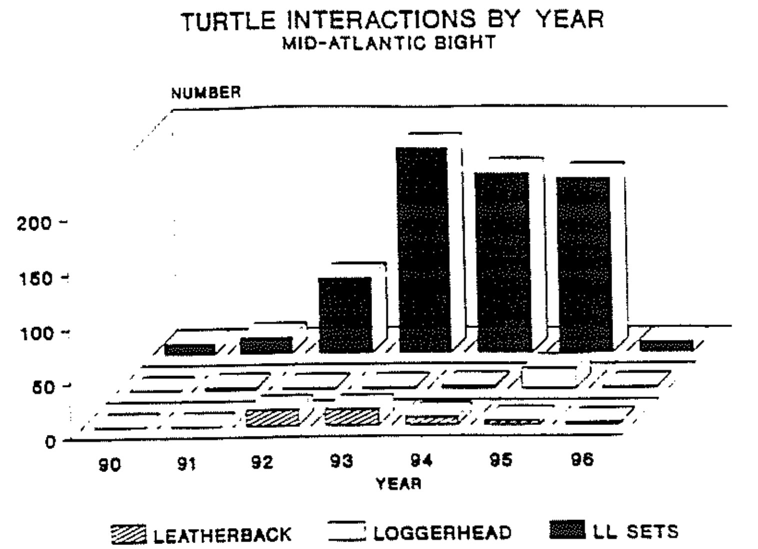
OBS	AREA	BHDYY	SETS	MEAN	STD	MEDIAN
1	5	90	10	0.00000	0.00000	0
2	5	91	15	0.13333	0.35187	0
3	5	92	69	0.01449	0.12039	0
4	5	93	186	0.00538	0.07332	0
5	5	94	163	0.01227	0.11043	0
6	5	95	159	0.11950	0.37929	0
7	5	96	10	0.10000	0.31623	0
8	6	90	13	0.00000	0.00000	0
9	6	91	19	0.00000	0.00000	0
10	6	92	36	0.02778	0.16667	0
11	6	93	76	0.05263	0.22478	0
12	6	94	75	0.02667	0.16219	0
13	6	95	43	0.04651	0.21308	0
14	6	96	13	0.07692	0.27735	0
15	7	91	14	0.21429	0.80178	0
16	7	92	81	0.02469	0.15615	0
17	7	93	75	0.12000	0.36613	0
18	7	94	61	1.37705	1.79967	1
19	7	95	65	1.58462	2.12788	0

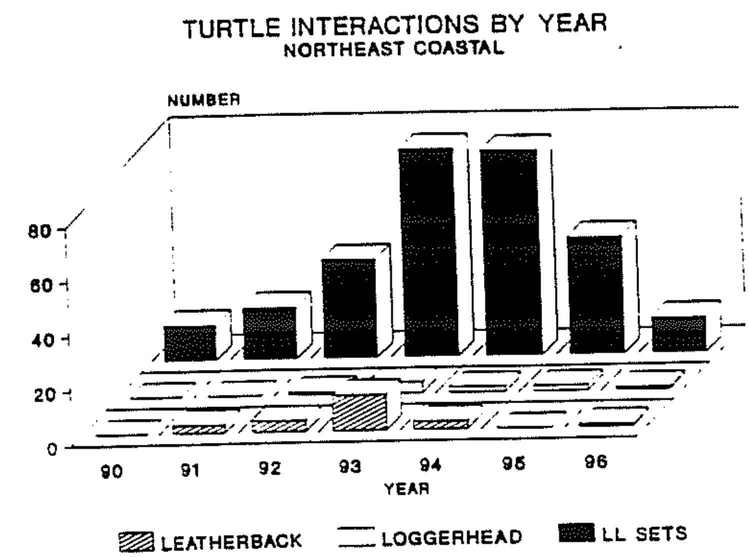
Table 3. Leatherback turtle interaction rates in number per set by area and year for the Mid-Atlantic Bight, Northeast Coastal, and Northeast Distant areas. Mean, median, and standard deviations are provided.

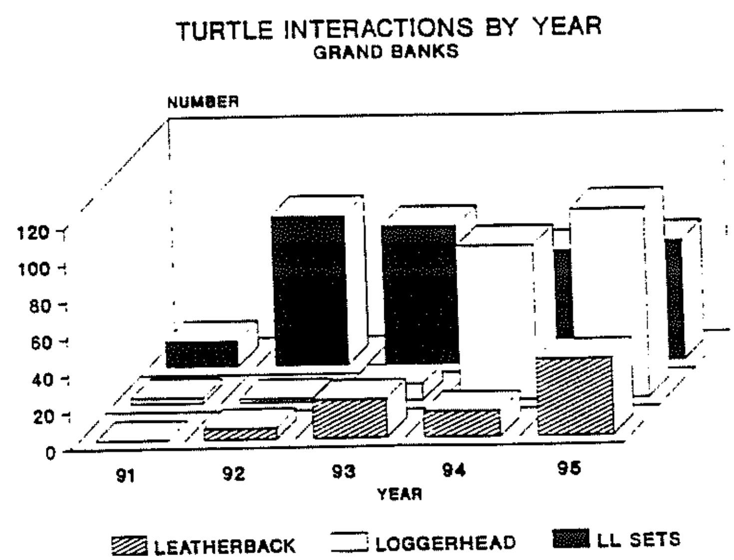
VARIABLE - LEATHERBACK TURTLES - NUMBER PER SET

OBS	AREA	BHDYY	SETS	MEAN	STD	MEDIAN
1	5	90	10	0.00000	0.00000	0
2	5	91	15	0.00000	0.00000	0
3	5	92	69	0.21739	0.48110	0
4	5	93	186	0.08065	0.34320	0
5	5	94	163	0.04294	0.23173	0
6	5	95	159	0.02516	0.15710	0
7	5	96	10	0.20000	0.42164	0
8	6	90	13	0.00000	0.00000	0
9	6	91	19	0.15789	0.37463	0
10	6	92	36	0.11111	0.39841	0
11	6	93	76	0.17105	0.52632	0
12	6	94	75	0.04000	0.19728	0
13	6	95	43	0.00000	0.00000	0
14	6	96	13	0.07692	0.27735	0
15	7	91	14	0.00000	0.00000	0
16	7	92	81	0.07407	0.26352	0
17	7	93	75	0.28000	0.70825	0
18	7	94	61	0.22951	0.64274	0
19	7	95	65	0.64615	1.00671	0

Figure 2. Plots of numbers of observed sets and numbers of turtles by year and area for the Mid-Atlantic Bight, Northeast Coastal, and Northeast Distant (Grand Banks) areas.







Since sea turtle interactions appear to be clustered events both regionally and within specific trips, especially with respect to loggerhead turtles, annual sampling characteristics must be considered. This will be especially true since observed sets within trips are not random and subsequent summaries provide clear evidence that variances in interaction rates by set differ significantly between trips within regions. Because sets within trips are not independent, it is essential that consideration be given to the number of trips observed by region and season in addition to the number of observed sets. The actual sample size in terms of statistical power for a number of analyses is probably not as great as would be expected from the number of sets observed, since a far smaller number of trips were actually observed within the time-area strata of interest. Table 4 lists the number of sets observed by area and quarter and this is plotted in Figure 3. Unfortunately, because of the differences in sampling between areas and quarters it is not possible to see the bars for the 3rd and 4th quarter samples in the Caribbean area and the 4th quarter in the FEC and SAB areas. These values are however provided in table 4. For comparative purposes, the number of trips observed by area and quarter are listed in appendix 2 (confidential data evident). Area-quarter summaries for trips will differ slightly in terms of numbers of sets and associated species composition when compared against summaries by set, because the program currently used to combine sets into trips assigns all trip catch and effort to the area and month recorded for the first set of the trip.

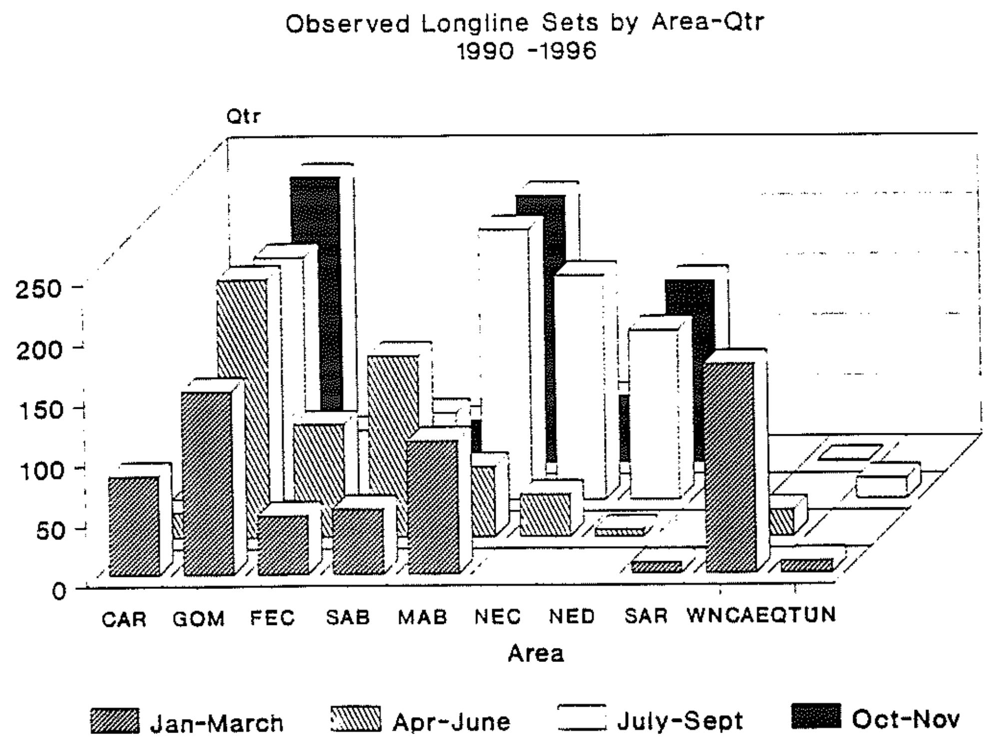
Table 4. Number of observed longline sets summarized across years by area and quarter.

Observed Sets by Area and Quarter

AREA	JAN. - MARCH	APRIL - JUNE	JULY - SEPT.	OCT. - DEC.	TOTAL
CAR	82	21	12	25	140
GOM	152	213	200	237	802
FEC	49	93	58	74	274
SAB	54	150	72	35	311
MAB	110	58	223	221	612
NEC	-	35	185	55	275
NED	-	6	140	150	296
SAR	9	-	-	-	9
WNCA	173	22	-	1	196
EQTUN	10	-	17	-	27
TOTAL	639	598	907	798	2,942

* Dashes are strata with no observed effort.

Figure 3. Number of observed sets summed across years by area and quarter.



TURTLE INTERACTIONS BY AREA AND AREA-QTR

After combining observations across years, summaries by area and by area-quarter indicate that there are significant regional differences in interaction rates. Table 5 lists the numbers of sets, total hooks, total catch, catch for major species groups, and the catch of all turtles, as well as loggerheads and leatherbacks separately. This demonstrates that loggerhead interactions are clearly dominated by incidents in the NED area (Grand Banks) where 75% of the interactions were recorded. While the NED area is also important for leatherbacks (40% of reported leatherbacks), interactions are more evenly spread out in the Mid-Atlantic Bight, Northeast Coastal, and Gulf of Mexico areas.

Table 5. The number of observed sets, total hooks, total catch, catch for major species groups, and the catch of all turtles, as well as loggerheads and leatherbacks separately, by area.

AREAB	SETS	HOOKS	CATCHALL	SWFS	TUNA	PELAGS	COSTS	FISHS	TURTS	LOGHTS	LTHBTS
1	140	60488	3255	1513	312	227	193	663	10	6	4
2	802	612738	22988	3530	8165	170	1925	6762	38	1	34
3	274	84381	5462	2471	632	186	965	822	12	3	4
4	311	156152	8598	2919	1236	289	1663	2076	19	11	8
5	612	408622	19444	2344	7618	3847	2178	1744	72	26	43
6	275	207636	10694	1321	3925	2100	268	1181	40	10	24
7	296	233284	21701	7141	1841	11632	9	429	294	200	84
8	9	3369	291	86	118	29	2	38	1	1	0
9	196	136395	4455	2461	501	305	15	1001	14	7	7
10	27	18229	1146	377	376	72	104	86	1	1	0

Figure 4 displays the number of loggerhead, leatherback, and <u>other turtles</u> caught by area. Table 6 lists the number of positive sets and the associated turtle catch by area and quarter.

Figure 4. Number of loggerhead, leatherback, green, and unknown turtles observed by area.

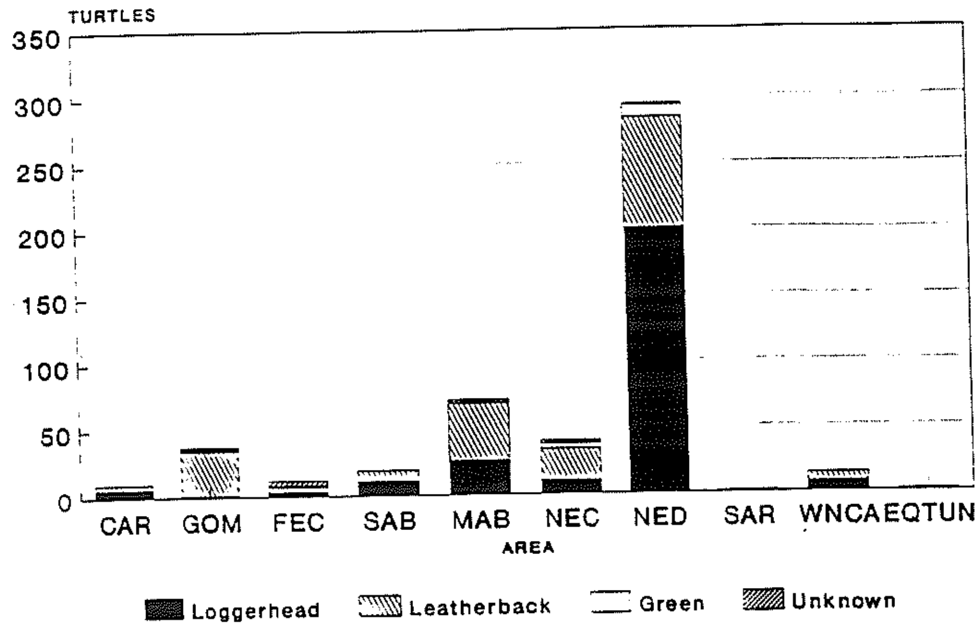


Table 6. The number of positive sets and the associated turtle catch by area and quarter.

Positive Sets and (Sea Turtles) by Area and Quarter

AREA	JAN. - MARCH	APRIL - JUNE	JULY - SEPT.	OCT. - DEC.	TOTAL
CAR	2 (3)	0	0	6 (7)	8 (10)
GOM	13 (16)	13 (13)	5 (5)	4 (4)	35 (38)
FEC	4 (4)	2 (2)	3 (3)	3 (3)	12 (12)
SAB	1 (1)	11 (12)	4 (4)	2 (2)	18 (19)
MAB	1 (1)	13 (16)	21 (25)	27 (30)	62 (72)
NEC	-	9 (10)	20 (26)	4 (4)	33 (40)
NED	-	3 (4)	62 (137)	52 (153)	117 (294)
SAR	1 (1)	-	-	-	1 (1)
WNCA	11 (11)	2 (3)	-	0	13 (14)
EQTUN	1 (1)	-	0	-	1 (1)
TOTAL	34 (38)	53 (60)	115 (200)	98 (203)	300 (501)

Figure 5 displays the number of observed sets and the number of positive sets by area, while Figure 6 presents the same information converted into a proportion of positive sets by area. This figure should be interpreted with care, particularly with respect to the SAR and EQTUN areas where only 9 and 27 sets were observed, respectively. In this respect it should also be noted that the CAR, NED, and WCNA areas all account for fewer than 20 observed trips.

Figure 5. The number of observed sets and the number of positive sets by area.

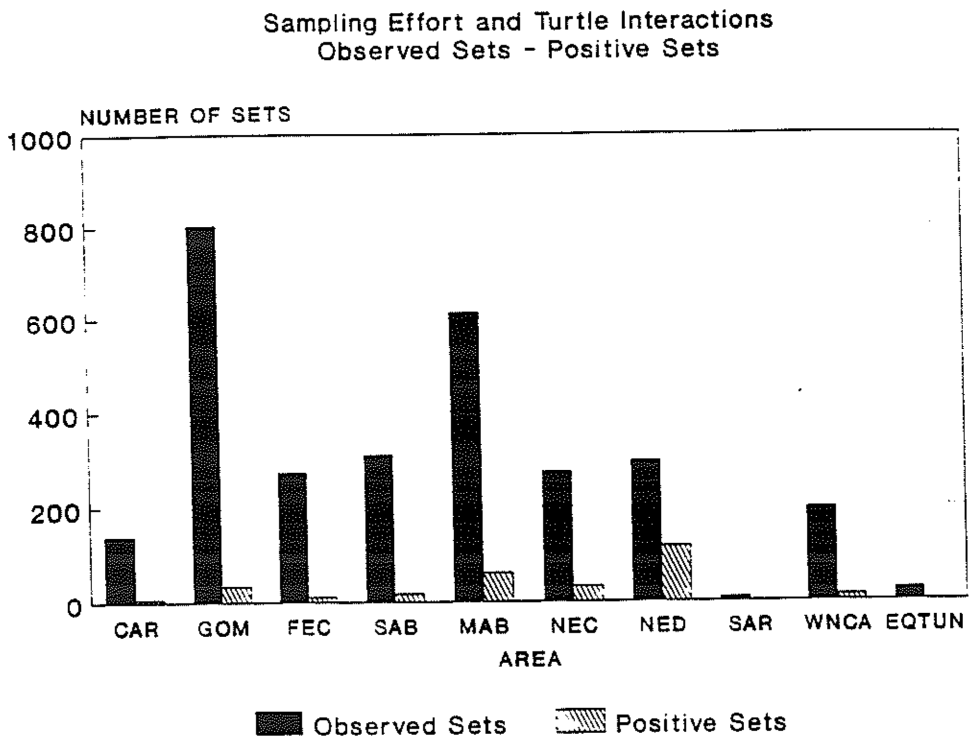


Figure 6. The proportion of positive sets by area.

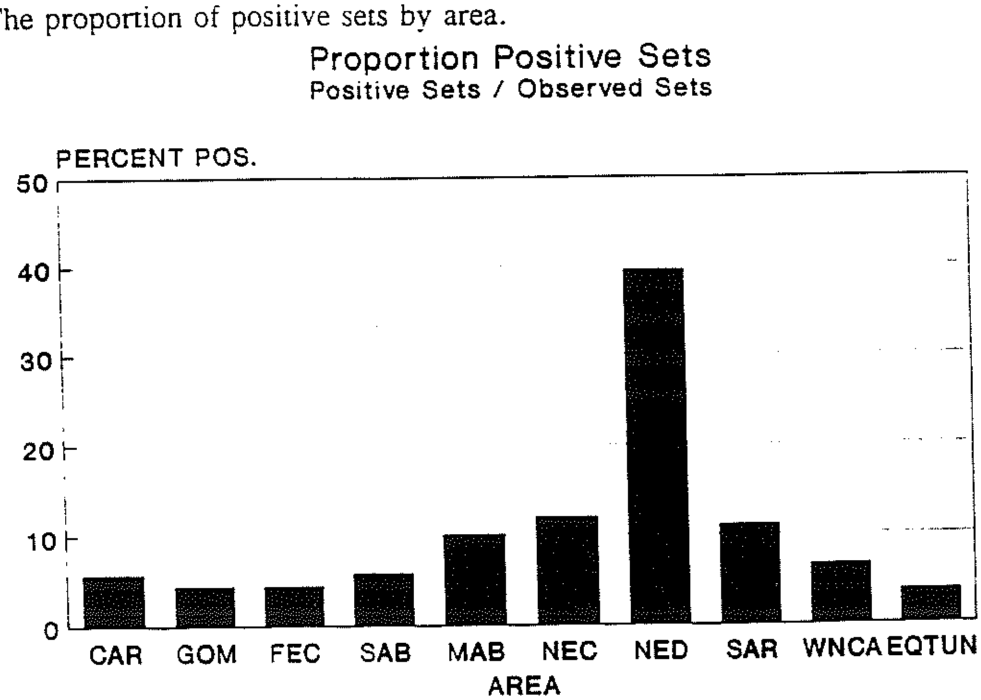


Figure 7 presents the total number of all turtles caught by area and quarter. This figure should be compared against the comparable plot of number of observed sets by area and quarter (Figure 3) to highlight the concentration of interactions in time and space. Tables 7 and 8 list the numbers of loggerhead and leatherback turtles by area and quarter. Table 9 lists the area and quarter catch totals for the 4 areas with the highest numbers of turtles reported.

Figure 7. The total number of turtles (all species) caught by area and quarter.

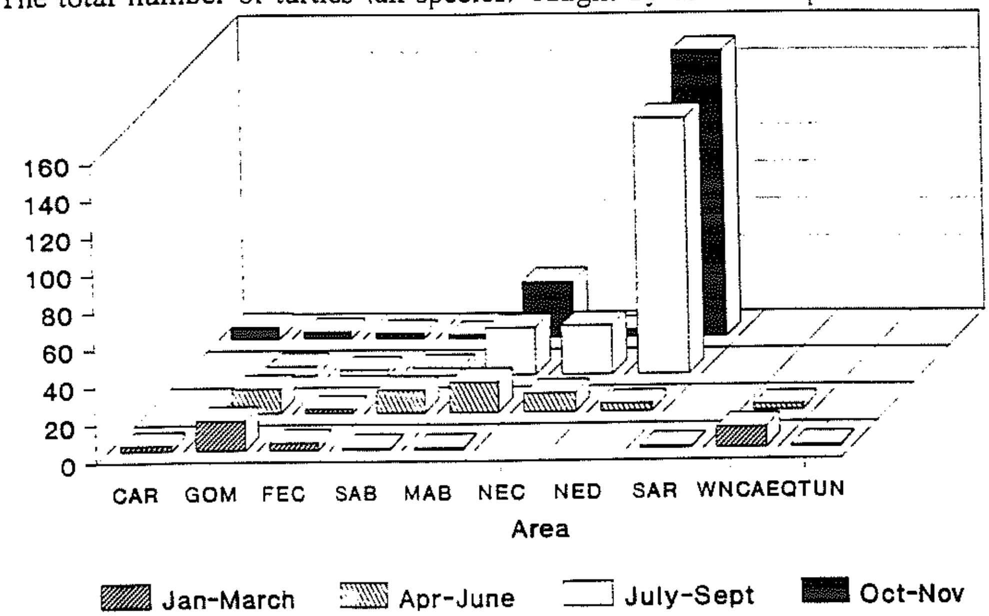


Table 7 - Numbers of loggerhead turtles reported by area and quarter.

Observed LOGGERHEAD TURTLES by Area and Quarter

AREA	JAN. - MARCH	APRIL - JUNE	JULY - SEPT.	OCT. - DEC.	TOTAL
CAR	2	0	0	4	6
GOM	0	0	0	1	1
FEC	2	0	0	1	3
SAB	1	8	1	1	11
MAB	0	7	13	6	26
NEC	-	3	4	3	10
NED	-	0	81	119	200
SAR	1	-	-	-	1
WCNA	7	0	-	0	7
EQTUN	1	-	0	-	1
TOTAL	14	18	99	135	266

Zeros are true zeros (no catch with observed effort) - Dashes are strata with no observed effort.

Table 8 - Numbers of leatherback turtles reported by area and quarter.

Observed LEATHERBACK TURTLES by Area and Quarter

AREA	JAN. - MARCH	APRIL - JUNE	JULY - SEPT.	OCT. - DEC.	TOTAL
CAR	1	0	0	3	4
GOM	14	12	5	3	34
FEC	0	0	2	2	4
SAB	0	4	3	1	8
MAB	1	9	11	22	43
NEC	-	6	17	1	24
NED	-	4	54	26	84
SAR	0	-	-	-	0
WCNA	4	3	-	0	7
EQTUN	0	-	-	-	0
TOTAL	20	38	92	58	208

Table 9. Area and quarter catch totals for the 4 areas with the highest numbers of turtles reported. Area 2 is the Gulf of Mexico. area 5 is the Mid-Atlantic. area 6 is the Northeast Coastal. and area 7 is the Northeast Distant (Grand Banks).

AREAB	QTR	SETS	HOOKS	CATCHALL	SWFS	TUNA	PELAGS	COSTS	FISHS	TURTS	TLOGHTS	TLTHBTS
2	1	152	123206	4157	839	1306	32	891	821	16	0	14
2	2	213	157493	5965	936	2289	55	343	1848	13	0	12
2	3	200	154721	6818	542	2430	38	381	2437	5	0	5
2	4	237	177318	6048	1213	2140	45	310	1656	4	1	3
5	1	110	68942	3110	798	445	715	957	118	1	0	1
5	2	58	38996	2004	155	932	306	215	302	16	7	9
5	3	223	149060	6147	421	2891	732	171	878	25	13	11
5	4	221	151624	8183	970	3350	2094	835	446	30	6	22
6	2	35	27043	1171	93	288	488	14	182	10	3	6
6	3	185	139888	7153	787	2710	982	201	864	26	4	17
6	4	55	40705	2370	441	927	630	53	135	4	3	1
7	2	6	3459	444	126	13	254	0	26	4	0	4
7	3	140	101670	10405	3585	530	5709	4	257	137	81	54
7	4	150	128155	10852	3430	1298	5669	5	146	153	119	26

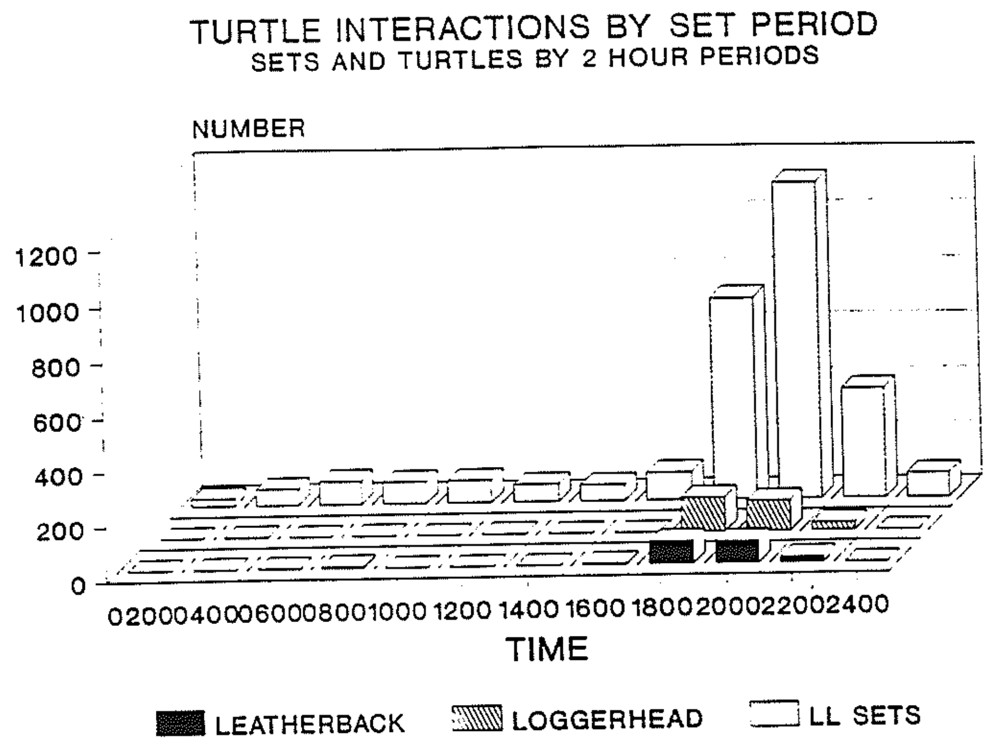
SEA TURTLE INTERACTIONS - ENVIRONMENTAL & GEAR PARAMETERS

While the preceding documents the significance of year, area, and quarter affects on turtle interactions, additional analyses were done on environmental (primarily sea surface temperature) and gear parameters. Preliminary analyses were conducted using all 2,942 observed sets, although with some parameters, missing values required elimination of some observation. It also became obvious that the dominance of Grand Banks observations in terms of accounting for most turtle interactions and the characteristics temperatures, gear, and operating styles for that area confound analyses of these parameters. Subsequently, analyses were focused on this area. As in previous tables and graphs it is important to consider differences in sampling when interaction rates are compared between specific variable values. In the following figures, two graphs are presented for most of the variables examined with the top panel including sampling information on the number of sets, while the lower panel presents the turtle catch information only. The resulting vertical scales are different in each panel.

Figure 8 presents turtle interactions compared against the time when the gear was set, where 2 hour set periods were established. The x-axis times are the military time at the end of the period. The data is obviously dominated by evening sets after 1800 hours (6 pm) as would be expected since most of the effort is targeted at swordfish which feed at night. Given the differences in numbers of sets in the 1601-1800 time period versus the 1801-2000 time period (734 vs 1142, respectively), the negligible difference in the number of turtles (219 vs 202) indicates that there may be a slightly higher interaction rate associated with early evening sets as opposed to late evening sets. The differences between the mean catch rates (numbers per set) between early evening (mean .298 - sd .877) and late evening (mean .177 - sd .684) support this tendency. The interactions evident in the lower panel in the 0600 and 0800 time periods probably reflect daytime sets in the Gulf of Mexico targeting yellowfin tuna.

Figure 9 presents turtle interactions compared against average set temperatures where average temperatures have been combined in 3 degree Fahrenheit intervals. Set temperatures were the average of values reported at the start and end of the set and start and end of the haul. The upper panel includes sampling effort in numbers of sets observed. The lower figure indicates wide thermal tolerances for both loggerhead and leatherbacks which was somewhat surprising. This indication, however, should be tempered since many of the loggerhead turtles were caught in the NED area (Grand Banks) where sharp termal gradients occur between slope and gulf stream water masses, especially when oceanographic eddys are present. For leatherbacks, the distribution is more peaked between the 60 and 69 degree fahrenheit intervals, and this is corroborated by higher mean catch per set values for these intervals.

Figure 8. Turtle interactions compared against the time when the gear was set, where 2 hour set periods were established.



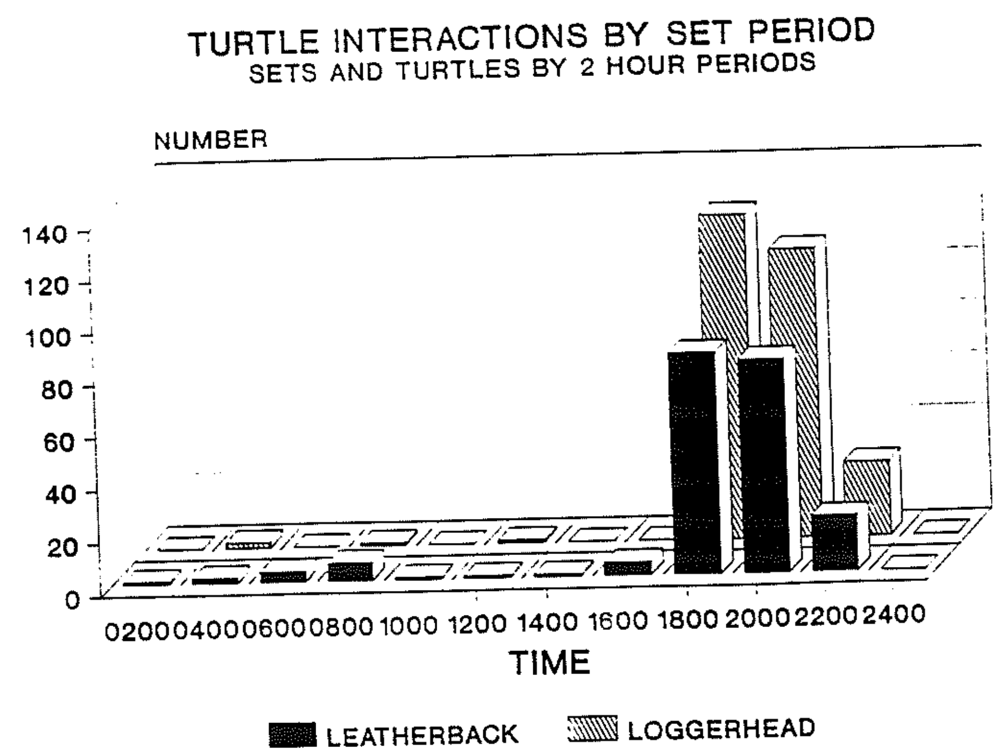
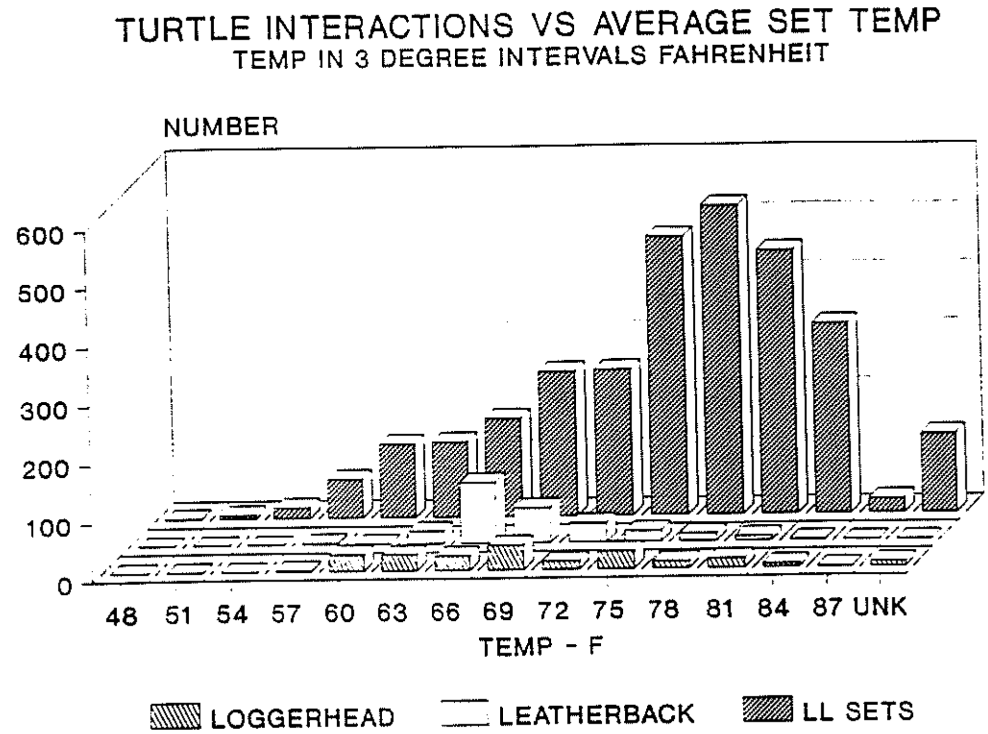
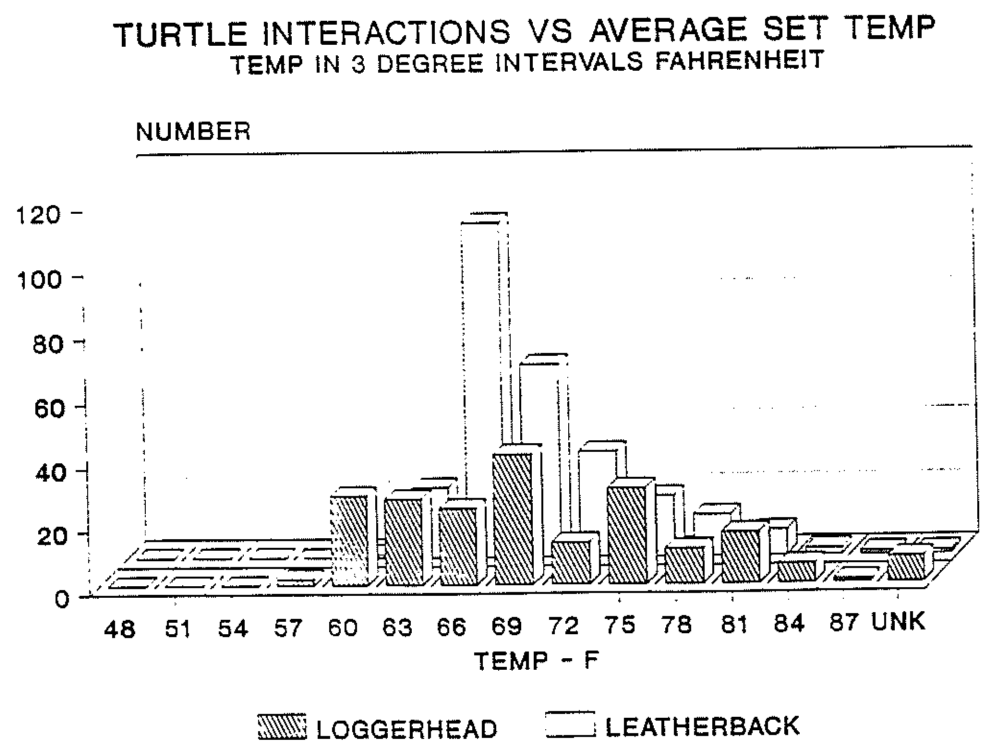


Figure 9. Turtle interactions compared against average set temperatures where average temperatures have been combined in 3 degree Fahrenheit intervals.



Temp values (3x(Integer(Mean Temp/3)))



Temp values (3x(Integer(Mean Temp/3)))

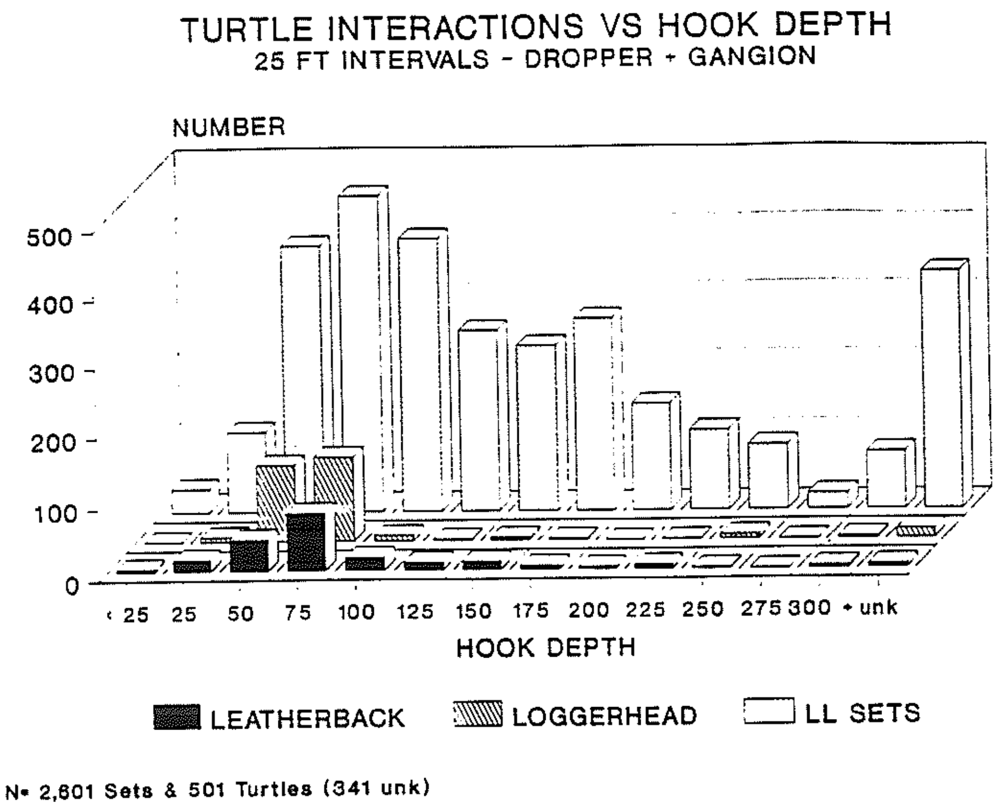
Figure 10 presents turtle interactions compared against hook depth which is assumed to equal the sum of the lengths of the dropper and gangion lines (2 panels). Figure 11 (1 panel) presents turtle interactions relative to the number of hooks between floats, a variable that also influences fishing depth by affecting the depth of the catenary between floats. These figures all support higher interactions associated with gear rigging characteristics that would result in a shallow fishing depths. Unfortunately, examination of fishing depth and hooks between float variables indicate that average values are clearly influenced by the area fished. This confounding of area with these variables indicates that conclusions based on these analyses would be premature.

Figure 12 presents turtle interactions against the proportion of lightsticks that were used in sets observed on the Grand Banks and for observed sets in the Northeast regions (MAB & NEC). This illustrates the confounding effect of area when most of the sets on the Grand Banks use 60% or more lightsticks as compared against the northeast region where most of the sets use less than 20% lightsticks. It is difficult to interpret this information, especially with respect to loggerhead interactions on the Grand Banks. The difficulty is in distinguishing the effect of lightsticks versus the effect of targetting swordfish along strong thermal gradients where the turtles are aggregating. Although additional analyses may be warranted, these graphs indicate that lightstick use does not provide a significant positive affect on turtle interactions, especially in comparison to other variables previously examined.

A preliminary examination of hook pattern types was also attempted. This was complicated by the fact that the available data in the area north of Cape Hatteras exhibited little diversity in hook size or pattern with slightly more than 95% of the observed sets characterized by two nearly identical J-style hooks produced by two different companies. In terms of areas south of Cape Hatteras, most of the data is from the SEFSC Observer program and questions about hook pattern codes and verification of the keypunched data has not been reviewed as thoroughly as the NEFSC data at this time (This will be undertaken under a MARFIN grant currently underway). However, in the Gulf of Mexico there were 630 observed sets with hook pattern data and 37.6% indicated that circle hooks (237 sets) were used. These sets accounted for 54% of the leatherback interactions (14 out of 26). This result should not be over-interpreted at this point in time until additional examination of area, depth, and month patterns are examined.

Based on the preceding, the affect of area and season provides the dominant influence on the likelihood of an interaction between longline gear and sea turtles, especially loggerhead turtles in the late summer and fall near the Grand Banks. Setting gear in sea surface temperatures equal to or exceeding 69 F would seem to increase the probability of encountering sea turles, especially in the fall when these temperatures are associated with warm core rings or the Gulf Stream. With respect to gear and operating practices, based on the available information small reductions in the probability of encountering sea turtles might be obtained by delaying the start of gear setting until after 1800 hours (6 pm), by setting 4 or more hooks between floats, and by using dropper and gangions that are longer in total length than 100 feet in length. Based on the preliminary analyses conducted to date, lightstick use does not appear to be a particularly influential variable, especially in comparison to the influence of temperature and frontal zone strength. A more detailed consideration of the Grand Banks data follows subsequently under the section on multiple interactions. Careful attention to conditions along a frontal system followed by attempts to fish colder and slightly deeper once turtles have been seen early in a trip, provide the best opportunity to limit subsequent interactions.

Figure 10. Sea turtle interactions compared against hook depth which equals the sum of the lengths of the dropper and gangion lines (top panel includes number of sets and turtle counts - bottom panel turtle counts only).



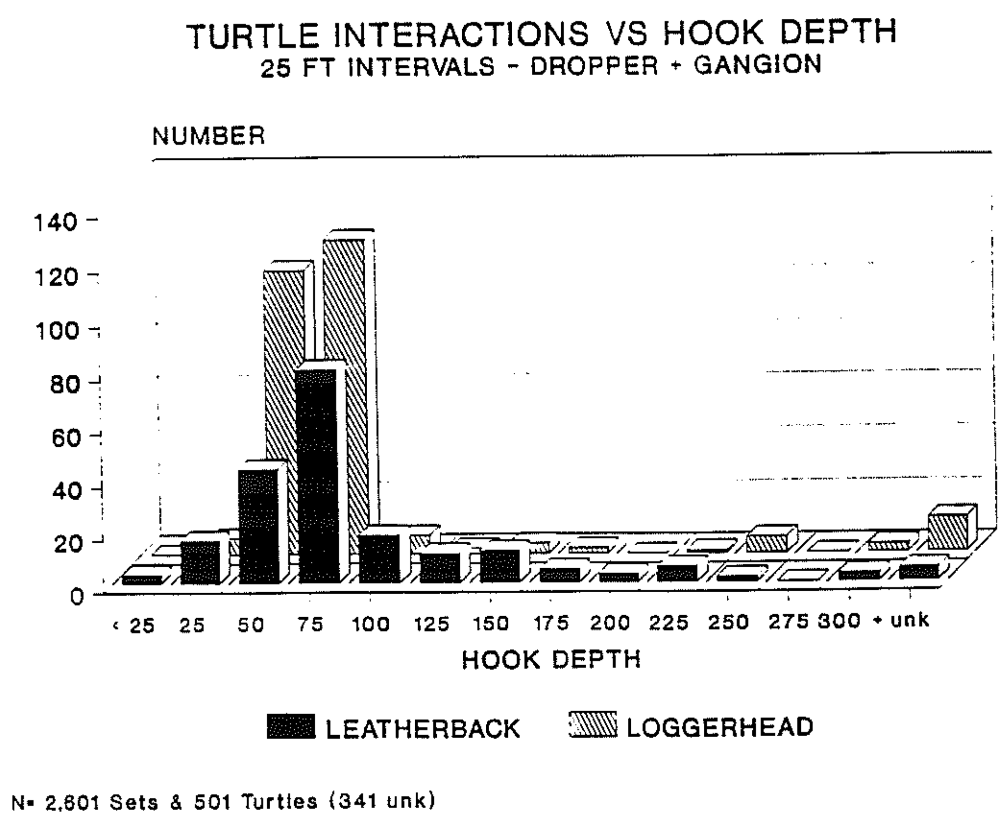


Figure 11. Sea turtle interactions relative to the number of hooks between floats. a variable that influences fishing depth by affecting the depth of the catenary between floats.

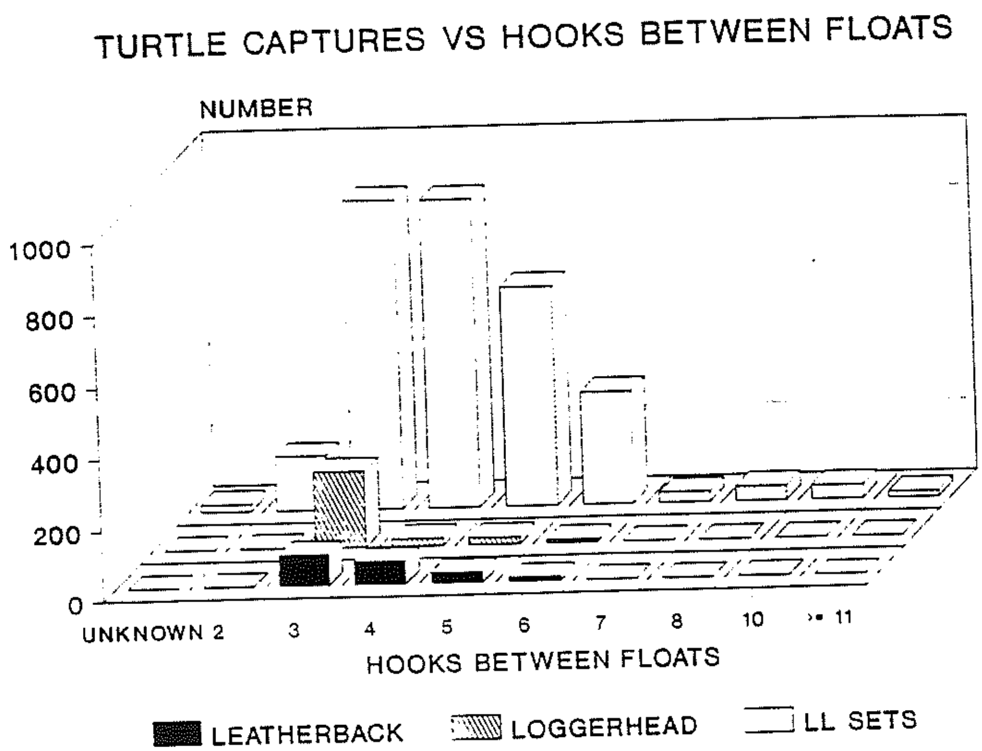
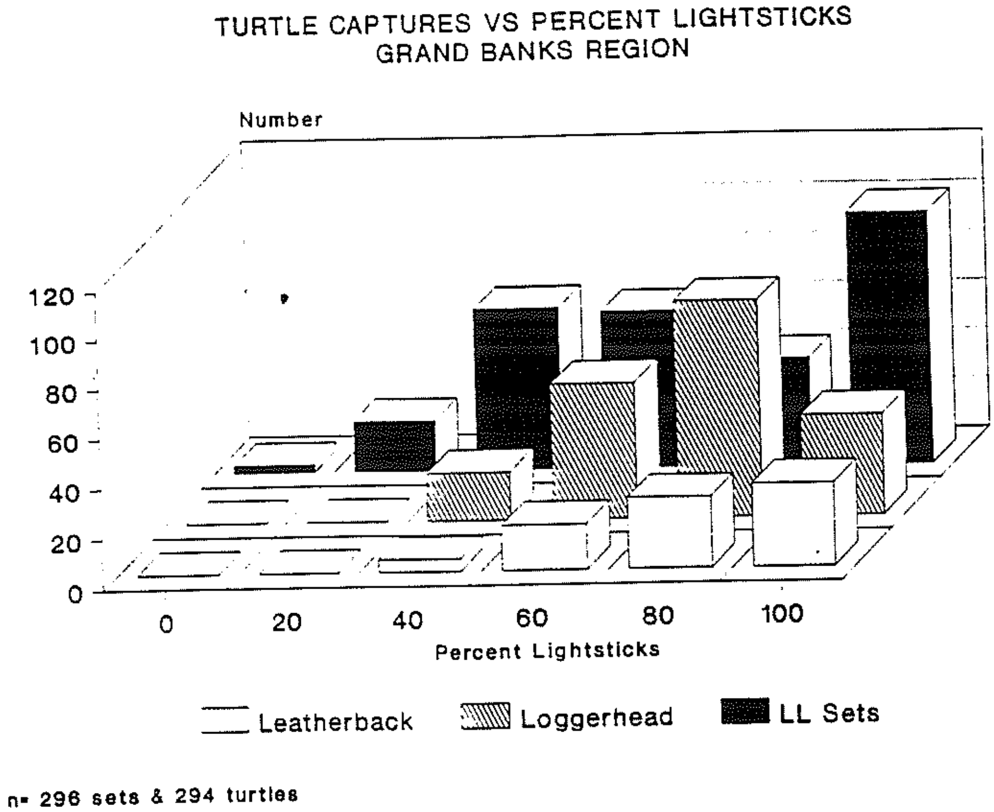
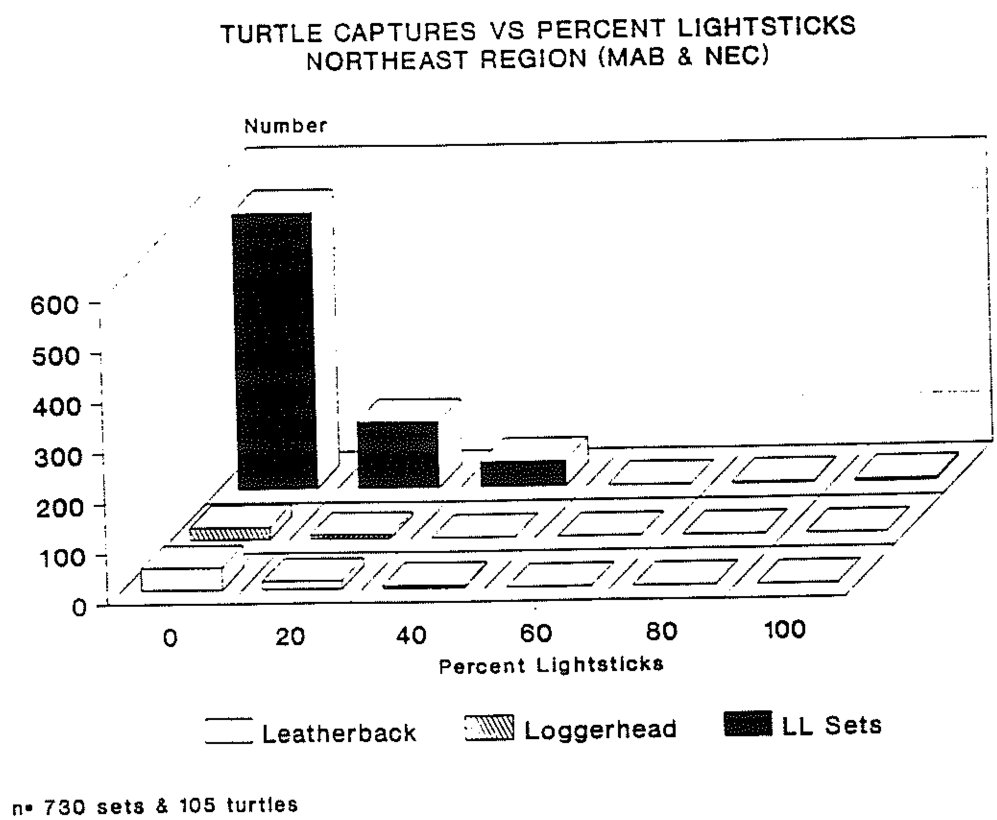


Figure 12. Sea turtle interactions versus the proportion of lightsticks that were used in sets observed on the Grand Banks (top panel) and for observed sets in the Northeast regions (MAB & NEC - bottom panel).





SEA TURTLE LONGLINE - MULTIPLE INTERACTIONS

Observers have recorded longline interactions with 501 sea turtles on 10.2% (300) of the observed sets (2,942) monitored between 1990 and 1996. On a per set basis, 90% of the observed sets had no turtle interactions, 7% interacted with one turtle, and 3% involved interactions with multiple turtles (Table 10).

Loggerhead and leatherback turtles had different probabilites of multiple captures on the same set. For loggerheads 68.1% were caught on sets with other loggerheads (31.9% caught singly), whereas only 31.7% of leatherbacks were caught on sets with other leatherbacks (68.3% caught singly). This pattern indicates that leatherbacks are more solitary whereas loggerheads have a greater tendency to aggregate.

The numbers of multiple interactions differ not only by species but also by area. The Grand Banks area (NED) is the only area where interactions of four (4) or more turtles occur on a single set and there are eighteen (18) sets with three turtles and twenty-two (22) sets with two turtles. In the mid-Atlantic bight (MAB) and Northeast Coastal (NEC) areas there are three (3) sets where three turtles were captured and eleven (11) sets where two turtles were captured. In the remaining southern areas, there were seven (7) sets that captured two (2) turtles. Multiple captures are clearly more prevalent on the Grand Banks and off the northeast coast. Multiple captures on single sets and clustered positive sets will affect statistical analyses to detect and evaluate options to reduce and or mitigate interactions.

Table 10. The number of turtles caught per set by species for loggerhead and leatherback turtles and for all observed turtles combined. Cell values are the number of sets associated with the turtle count listed in column 1.

Interactions (Turtles) per Set	Loggerhead Turtles (Sets)	Leatherback Turtles (Sets)	All Turtles (Sets)
0	2,804	2,774	2,642
1	85	142	211
2	22	18	40
3	12	4	21
4	8	2	9
5	3	2	10
6	4		5
7	3		2
8			1
9	1		1

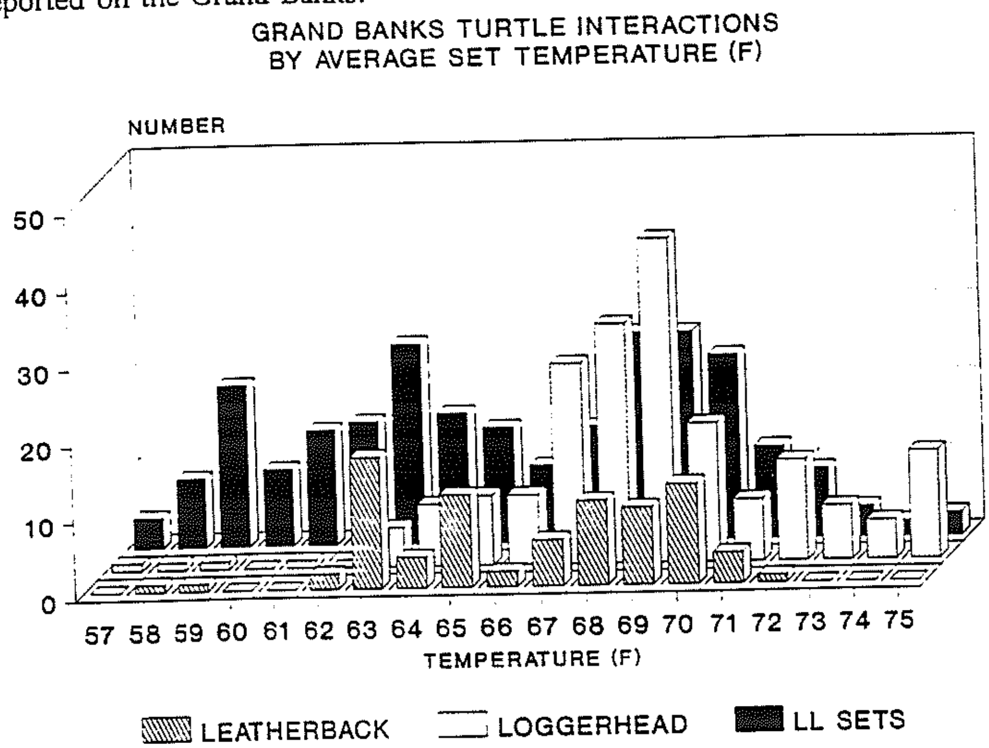
Examination of total turtle interactions by trip highlighted a limited number of trips in the NED area (Grand Banks) which accounted for a disproportionate number of turtles, especially loggerheads. The top 8 trips out of 395 (2%) in terms of total numbers of turtle interactions accounted for 5% of the sets (146 out of 2,942) and 51.5% of the reported turtles. Dramatic differences in the number of interactions reported by year, especially for loggerhead turtles, have been displayed previously (Figure 2 - lower panel). Between 1991 and 1993, 170 observed sets accounted for 50 turtles; whereas in 1994 and 1995 a smaller number of observed sets (126) accounted for almost five (5) times the number of turtles (244). This dramatic difference is primarily the result of loggerhead interactions. Leatherback interactions increased from 27 turtles between 1991 and 1993 to 56 turtles in 1994 and 1995.

An examination of interactions by average set temperature for sets in the NED area (Grand Banks) raise the possibility that average set temperatures equal to or below 67 F account for significantly lower numbers of turtles, especially loggerheads. Figure 13 displays the number of sets and the numbers of loggerhead and leatherback turtles by average set temperature as in previous figures. Figure 14 displays effort in numbers of sets for the Grand Banks observations from 1991 to 1993 versus the 1994 and 1995 sets. In the earlier time period 55% of the sets were in average temperatures below 65 degrees Fahrenheit as compared against 33% of the sets in the later year. Figure 15 displays the associated turtle catch by average set temperature in the two time periods. Figure 16 (2 panels) displays the effort (sets) and turtle interactions in the same graph for each of the two time periods. A simple explanation is not self evident, except to state a preliminary conclusion that turtle interactions are probably lower in colder water and that this picture is probably complicated by the strength of the frontal zones across which the gear is set and where the ends of the gear end up during setting and hauling with respect to either the cold or warm side of the fronts.

Prior to examining all of the available observer data, preliminary analyses had revealed the fact that a small number of Grand banks trips accounted for a very large number of turtles. One vessel owner copied the observer records shortly after the trip and sent them to me to review. Subsequent discussions with the owner and the Captain indicated that the unusually large number of interactions occurred while he was fishing a decaying warm-core ring of the Gulf stream that was surrounded by colder water. Turtle interactions, as well as daily sightings, increased during the trip as the ring diminished in size both linearly and in depth. Multiple captures of the same turtle were thought to occur on subsequent days. Observers have noted the presence of clean hooks already in the jaws of captured turtles. Gear dimensions were shorter than usual because the ring was essentially a rather shallow cup of warm water in a larger basin of colder water north of the Gulf Stream.

As a result of this discussion and analyses funded by this grant, 11 trips with set location and temperature data were sent to an Oceanographic Mapping consulting service to get an independent assessement of the likelihood that specific trips where strongly associated with warm core rings or other significant oceanographic features. The 11 trips included 7 from the NED area and 4 from the northeast region (MAB & NEC). The consultant felt that almost all of the trips were clearly associated with strong frontal systems with water temperatures characteristic of Gulf Stream water. While several of the trips were east of 44 degrees west and beyond the range of the available sea surface temperature charts, the associated temperatures also indicated warm Gulf stream water. More extensive evaluation of remotely sensed sea surface temperatures for all of the trips on the Grand Banks and information on inter-annual variability in the number, size, and duration of warm core rings north of Cape Hatteras might shed important information on interaction patterns between sea turtles and pelagic longline fisheries.

Figure 13. The number of sets and the numbers of loggerhead and leatherback turtles (upper panel) and the number of turtles alone (lower panel) by average set temperature reported on the Grand Banks.



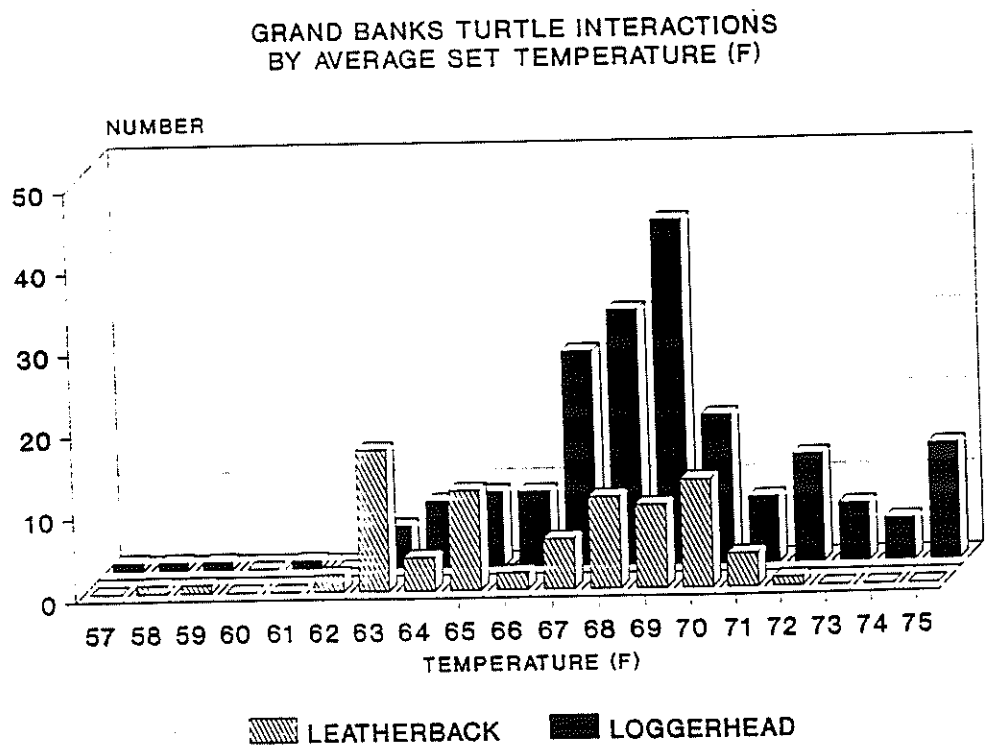


Figure 14. Effort in numbers of sets for the Grand Banks observations from 1991 to 1993 versus the 1994 and 1995 sets by temperature (set average degrees Fahrenheit).

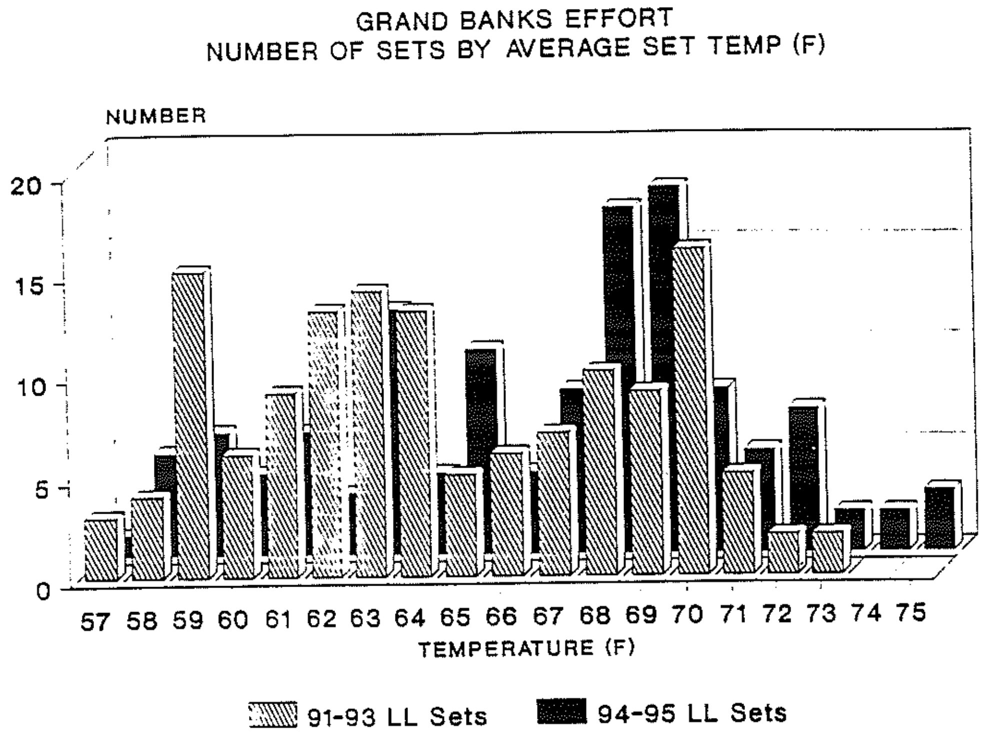


Figure 15. Sea turtle interactions by average set temperature on the Grand Banks in the two time periods.

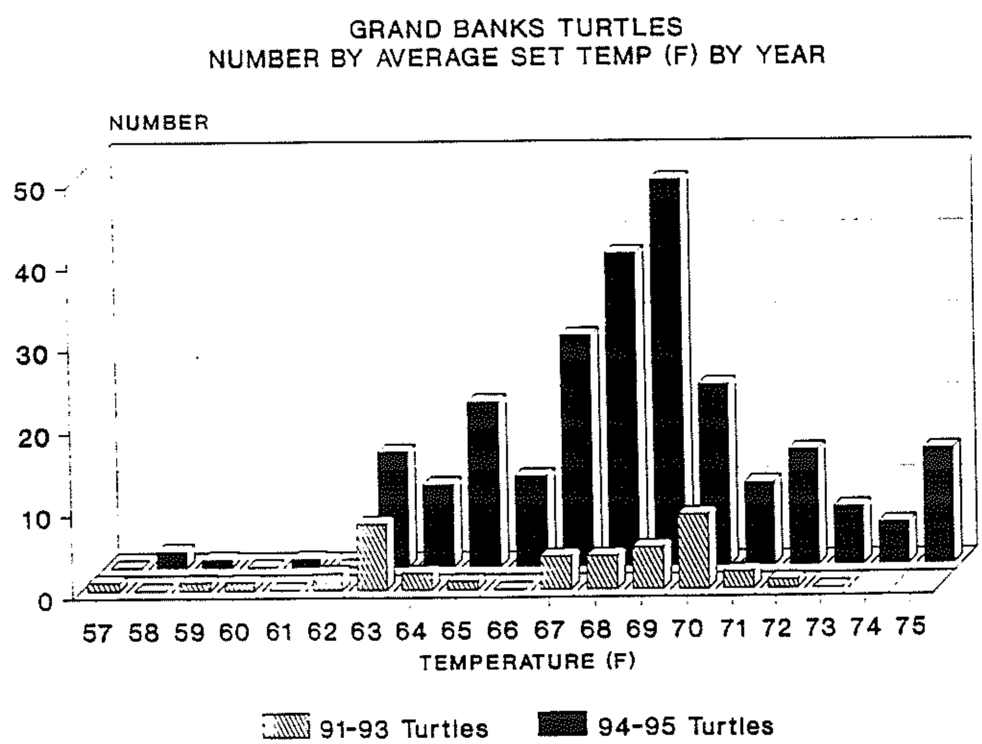
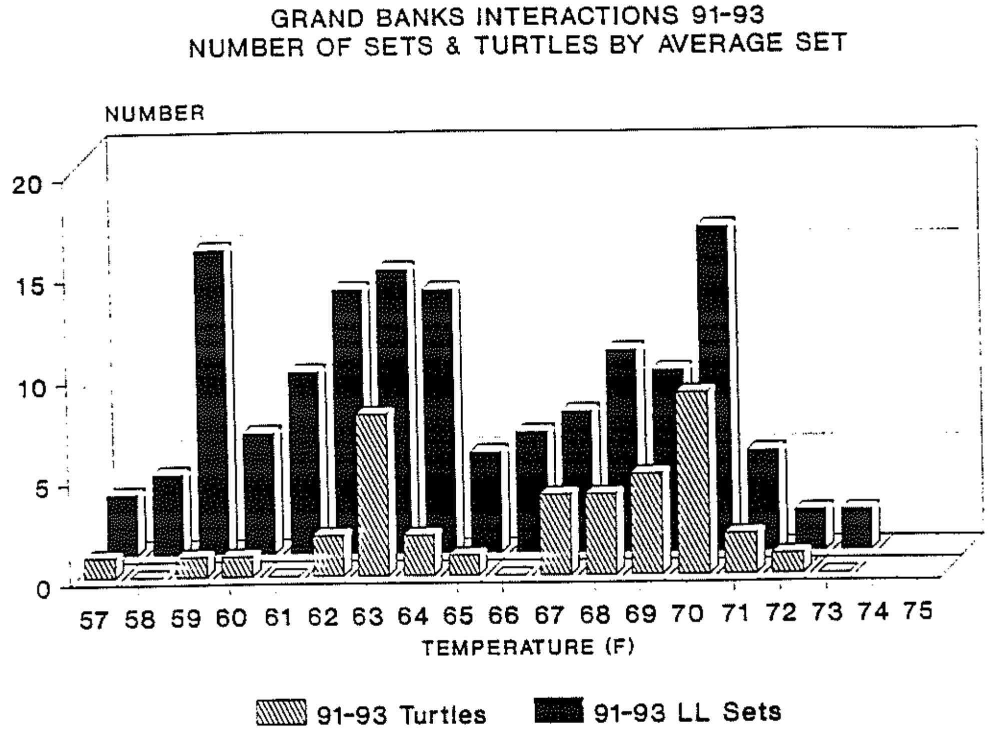
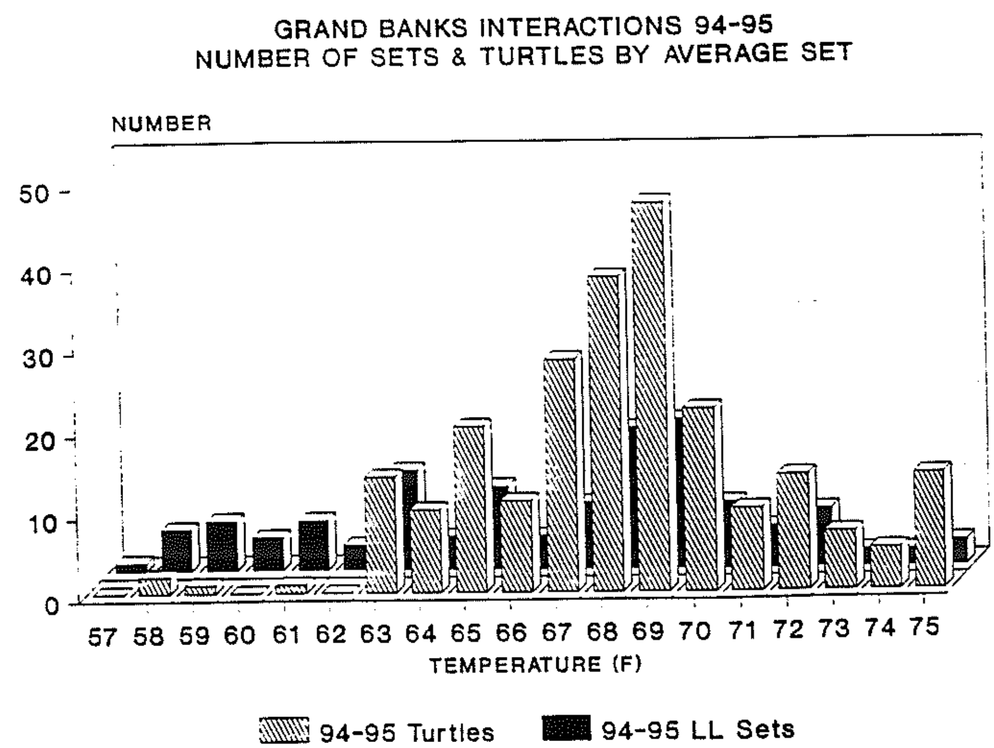


Figure 16. Grand Banks effort (number of sets) and number of turtle interactions for the period 1991 to 1993 (upper panel) compared to the 1994 and 1995 time period (lower panel).





TURTLE STATUS

Six (6) of the observed 501 sea turtles were recorded as released dead, while the two that were listed as unknown status were coded as released alive. Observer release codes for the remaining 493 turtles (98.4%) indicate that they were released alive.with most coded as not injured. Interaction forms indicate that turtles were tangled in the gear, snagged by hooks on the shell, flippers, and head, and also caught by hooks in the jaw and occasionally in the throat. In a number of cases observers indicated that captured turtles had other visible hooks in the jaw. Improved forms and observer protocols are critically needed to define interactions and the nature of injuries.

In addition to status codes, which record the condition of the turtle upon retrieval, more detailed animal condition codes and entanglement situation codes were developed in the later years of the observer programs. These codes have not been reviewed with respect to the SEFSC data at this time, and there is a need to re-examine the coded values which are summarized below for the NEFSC records to verify that the codes have been consistently applied by different observers. Tables 11, 12, and 13 provide a very preliminary summary of the existing coded values for each turtle documented in the observer data base. These were only reviewed by one person and a more thorough review is essential.

Table 11. Frequency tabulation of the values for sea turtle animal condition codes.

ANIMCOND		Frequency
0	- Unknown	1
1	- Alive, condition unknown	24
2	- Alive, not injured	75
3	- Alive, injured	28
4	- Alive, gear in/around mouth	154
5	- Alive, gear in/around flipper	21
6	- Alive, gear in/around another single body part	9
7	- Alive, gear in/around several body parts	8
8	- Alive, seen by Captain only	1
11	- Dead	1
99	- Unknown or blank	179

Table 12. Frequency tabulation of the values for sea turtle entanglement codes.

ENTANG		Frequency
0	- Unknown	8
1	- Fell from gear	3
2	- Fell from gear before exiting water	4
3	- Fell from gear once hauled	1
5	- Removal requires cutting of gear	127
6	- Removal does not require cutting gear	34
7	- Foul hooked, cut from gear	108
8	- Foul hooked, removed from gear	26
99	- Unknown or blank	190

TABLE 13. Crosstabulation of the number of turtle observations with combinations of animal condition and entanglement codes.

ENTANG Frequency	ANIMCOND 0	1	2	3	4	5	6	7	8	11	99	Total
0	0	4	2	1	0	0	1	0	0	0	0	8
1	0	1	0	1	1	0	0	0	0	0	0	3
2	0	1	1	1	0	0	0	1	0	0	0	4
3	0	0	0	0	1	0	0	0	0	0	0	1
5	0	7	31	11	65	3	5	5	0	0	0	127
6	0	3	24	5	2	0	0	0	0	0	0	34
7	0	5	5	3	72	16	3	2	1	1	0	108
8	1	1	4	5	13	2	0	0	0	0	0	26
99	0	2	8	1	0	0	0	0	0	0	179	190
Total	1	24	75	28	154	21	9	8	1	1	179	501

RECOMMENDATIONS

In light of the work accomplished under this contract there are several obvious analyses and reviews that would further the understanding of the nature and conditions that influence sea turtle and pelagic longline interactions. Several tasks that should be conducted include:

a) A rigorous and thorough review of the animal condition and entanglement situation codes to ensure consistency between time periods and observer programs followed by the establishment of simpler, standard protocols for all observer programs emphasizing the location of the hook in each encounter. Comparisons of Atlantic observer protocols with Pacific protocols should be conducted and some of the standard Pacific variables (ie. hook number, proximity to lightsticks) should be included in Atlantic procedures.

b) Similar data verification tasks, particularly with respect to hook types, gear dimensions, bait types and conditions are underway as part of existing grants dealing with the SEFSC observer data. Comparable analyses of the SEFSC data will be conducted, especially with respect to hook differences. It is apparent that many turtles are foul hooked and there is a distinct possibility that these interactions might be significantly reduced <u>if</u> different hook styles have different foul hooking rates (ie. circle vs J hooks).

c) Given the differences between interaction rates for trips in the same region, especially off the Grand Banks, an examination of the target species catch rates, discard rates, and sizes of target species landed for trips with turtle interactions should be conducted. This would provide valuable data on the implications of efforts to avoid interactions by attempting to set the longline gear in colder temperatures along frontal zones.

In order to help responsible commercial fishermen enhance their ability to avoid sea turtle interactions, educational outreach and cooperative research projects that utilize the information developed under this contract and results from similar work in the Pacific should be undertaken. In particular, vessel owners and Captains that fish off the Grand Banks should be contacted immediately and the results of these analyses should be provided for their review. During the 1998 and subsequent seasons, additional observer coverage for the Grand Banks should be funded to provide at-sea assistance with respect to collecting data on possible avoidance measures that could be attempted once the first interactions occurred on a trip. Based on the analyses conducted, the following avoidance procedures should be attempted: a) set the gear later at night, after 2100 hours (9pm), b) increase the number of hooks between floats or gangion and dropper lengths, c) attempt to set the gear along the colder side of the eddy, avoiding where possible water temperatures greater than 68 F. Additionally, given the experience that fishermen are having with circle hooks for other species, Captains should consider attempting sets with significant numbers of circle hooks to evaluate whether foul hooking and the incidence of gut or throat hooked turtles could be reduced. Finally, additional educational material on release protocols along with biological information on turtle feeding habits and migration patterns would undoubtedly be helpful for vessel Captains.

To compliment ongoing analyses of existing observer data and voluntary experiments by Captains, archival tagging, which is occurring in the Pacific, should be given a very high priority along with specifically designed gear experiments.

Appendix 1. Annual summaries of observed pelagic longline sets by area and quarter.

BHDYY = 90

AREAB Frequency	QTR 3	Total
5	10	10
6	13	13
Total	23	23

BHDYY = 91

AREAB Frequency	QTR 3	4	Total
5	3	12	15
6	17	2	19
7	14	0	14
Total	34	14	48

BHDYY = 92

AREAB Frequency	QTR 2	3	4	Total
1	0	0	11	11
2	16	8	37	61
3	18	8	15	41
4	13	20	0	33
5	6	7	56	69
6	1	29	6	36
7	0	35	46	81
Total	54	107	171	332

BHDYY = 93

AREAB Frequency	QTR 1	2	3	4	Total
1	21	9	0	10	40
2	50	79	52	64	245
3	20	33	15	16	84
4	17	22	20	9	68
5	47	18	54	67	186
6	0	20	52	4	76
7	0	6	34	35	75
9	52	0	0	1	53
Total	207	187	227	206	827

BHDYY = 94

AREAB / Frequency	QTR 1	2	3	4	Total
1	35	0	0	0	35
2	27	33	49	47	156
3	18	24	26	16	84
4	9	32	13	4	58
5	24	13	72	54	163
6	0	14	37	24	75
7	0	0	18	43	61
9	19	0	0	0	19
Total	132	116	215	188	651

BHDYY = 95

AREAB / Frequency	QTR 1	2	3	4	Total
1	23	12	12	1	48
2	44	66	47	54	211
3	6	14	5	12	37
4	15	31	7	0	53
5	39	21	68	31	159
6	0	0	24	19	43
7	0	0	39	26	65
9	61	22	0	0	83
Total	188	166	202	143	699

BHDYY = 96

AREAB / Frequency	QTR 1	2	3	4	Total
1	3	0	0	3	6
2	31	19	44	35	129
3	5	4	4	15	28
4	13	52	12	22	99
5	0	0	9	1	10
6	0	0	13	0	13
8	9	0	0	0	9
9	41	0	0	0	41
10	10	0	17	0	27
Total	112	75	99	76	362

Appendix 2. The number of observed trips by area and quarter. NOTE - this table identifies strata where it is likely that the number of observations are so limited that the entire strata is confidential.

Observed TRIPS by Area and Quarter

AREA	JAN. - MARCH	APRIL - JUNE	JULY - SEPT.	OCT. - DEC.	TOTAL
CAR	9	2	2	3	16
GOM	25	34	36	33	128
FEC	10	26	21	19	76
SAB	10	17	11	4	42
MAB	11	5	34	28	78
NEC	-	2	17	6	25
NED	-	1	8	8	17
SAR	1	-	-	-	1
WCNA	10	1	-	-	11
EQTUN	-	-	1	-	1
TOTAL	76	88	130	101	395

* Dashes are strata with no observed effort.